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FINAL RESEARCH REPORT ON THE 1998-2000 EOARD PROJECT SPC-98-4052:

SOLAR RADAR DETECTION of CORONAL MASS EJECTIONS (CMEs) [CONTRACT No F61775-98-WE088]

1. The main tasks (goals) of the PROJECT SPC-98-4052

The main task of this project is the preparation and realization of radar investigations of the sun with the goal of detecting coronal mass ejections (CMEs). A CMEs is one of the most important and interesting phenomena in the study of solar physics and solar terrestrial relations. According to preliminary estimations high frequency radars can be one of the most effective means for the detection of these phenomena. This technique is most effective if used in a be static configuration, for example, the use of the Russian SURA high frequency transmitter and the Ukrainian UTR-2 receiving antenna array.

2. Introduction

Our previous EOARD project 1997 demonstrated the need for continued experiments in high frequency solar radar experiments for CMEs detection and solar corona investigation. New solar radar experimental means and methods as well as some results are presented in our preliminary report. Among the new regimes to be investigated are chirped transmissions, shorter pulse widths and longer codes, high spatial resolution, receiving of harmonic components of reflected signals, and more detailed investigation of the propagation medium (using WIND observations, for example).

The principal difficulty of these experiments is the strong propagation medium influence, which was practically absent in the J.C. James experiments at 38 MHz [1]. In this connection, high attention was paid to monitoring the medium with the help of reference radio sources, such as the Sun, Cas A, Cyg A, Vir A, Tau A. During these experiments, we determined the following: 1) the excess galactic temperature over the system noise temperature, 2) the variations of the flux density of radio sources due to refraction, scattering and absorption, 3) comparison of high frequency (20-30 MHz) and low frequency (16.7-8.9 MHz) data. We used the multiplication regime of the UTR-2 radio telescope as well as the full power registration mode for the N-S and E-W antennas. We can see from **Figure 1** that there is strong propagation medium influence at the lowest frequencies. Also, the influence of monochromatic interferences and lightning are more evident at the lowest frequencies. Great attention was paid to the realization and investigation of the multi-beam regime, and the increasing of the spatial separation of the beams. During the period from 10 June to 4 July 1998, we carried out solar radar experiments.

Significant improvement of experimental facilities of the UTR-2 radio telescope for solar radar experiments has been made. In June-July, 1998, a great amount of experimental data was obtained. During these experiments, the

initiator of this project, Dr. Paul Rodriguez, Naval Research Laboratory, USA, was at the UTR-2 radio observatory. It is interesting to estimate the possibility of increasing the transmission frequency up to 25 MHz from the viewpoint of propagation medium and interferences influence. Such high frequencies may allow us to obtain nearly daily radar measurements of the solar corona and possible CMEs detection.

3. Preliminary information about CMEs

After the J.C. James experiments was known that the Decameter (DKM) solar observations are of great importance at interpretation of solar radar experiments. This is result of the fact that decameter range is the optimal one for these experiments. At the same time solar activity in this range has influence on formation of reflected signal. Really there is a good correlation between reflection effective cross sections and numbers of type III bursts, infrequent type II bursts and type IV continuum [1,2].

On the other hand it is quite possible that at some conditions reflected signal is formed at scattering by coronal mass ejection (CMEs). In this case analysis of DKM activity could be used for short-term (some hours) forecasting of CMEs. Such opportunity is appeared because CMEs is accompanied by DKM activity. In connection with this we want to point to the fact that high cross sections in James's experiments [1] correlate with such DKM activities that are typical for CMEs. So it is quite possible reflections from CMEs have appreciable contribution in radar cross-sections.

3.1. Radio astronomy manifestation of CMEs

CME is a coronal phenomenon that is accompanied by ejection of considerable coronal matter with magnetic fields in high layers of the solar corona. Their typical parameters are time interval – from tens minutes to some hours, distances – to some $R_{\odot}$, velocities – from tens to 10^3 km/s and masses – $10^{15} \div 10^{16}$ g.

Lately it becomes obviously that CMEs is one of the fundamental manifestation of solar activities and is one of the important section into solar-terrestrial physics. CMEs take out the main part of flare energy ($10^{31} \div 10^{32}$ erg), so it is difficult to imagine a scenario of large solar flares without CMEs [3]. Its rising is accompanied by essential reconstruction of coronal magnetic fields. In interplanetary space CMEs causes such phenomena as shocks, magnetic clouds, geomagnetic disturbances etc. Its role is important in solar proton events – CMEs provide their way out and may be acceleration of energetic particles that determine radiation situation near the Earth.

Because of its different manifestation researchers paid a great attention to CMEs last two decades. Results of their studying are published in hundreds papers and overviews (e.g. [4] and bibliography there). But all of them are devoted to passive methods of researches in microwave, meter and hectometer range. Active radar method was not used till now. Besides there are absent passive researches of CMEs in the optimal for radar DKM range. Development of these methods will lead to new results. For their interpretation data from close ranges need to be used. So at first we overview available results.

3.2. Nature and parameters of CMEs

Depending on phenomena with which CMEs are connected they fall into two classes: type F and type EP. Type F CMEs are associated with long nonimpulsive flares. Type EP CMEs are observed after eruption of prominence or disappearance of dark Hα filaments near active region. As a matter of fact nature of these CMEs are the same. Difference is in their energetic: type F CMEs is stronger events.

Flare is accompanied CME if it has high flare importance, duration from tens minutes to hours, two Hα ribbons, altitudes of diffusive (in soft X-rays) loops $(30\text{-}70)*10^3$ km, eruptive prominence, high intensities of microwave radio emission, type II burst driven wave shock and moving type IVm burst. Usually CMEs are absent at impulsive flare of < 30 min. duration with low ($= 10^4$ km) altitude loops, low intensity of cm radio emission, type II bursts (blast wave shock) and stationary type IVs burst [3-6].

CMEs velocities are in the range 100 – 800 km/s for type EP and in the range 300 – 1800 for type F. At altitudes $2 \div 3$ $R_{\odot}$ CMEs are accelerated up to 50 m/s^2 [7]. Type EP CMEs are not

decelerated in the 1 au range because of their lower velocities. Type II and type IV bursts are observed only for CMEs with high (> 400 km/s) velocities.

Main parameters of CMEs are changing during solar activity cycle. In minimum activity CMEs are concentrated near 0° latitude and in maximum one they are observed even near poles.

CMEs appearance correlates with Volf number: at 140 – 160 (1979 – 1981) Volf numbers occurrences are 0.1 – 1.8 per day and at 15 – 40 – they are 0.1 – 0.5 per day.

According to [8] time interval between successive CMEs from the same active region is more than 10 hours, and for disappearing filaments (eruptive prominence) = 1 day. It seems such time needs for restoration of magnetic structure and energy accumulation in the corona.

3.3. Connection with flares

Widespread opinion is that CMEs is result of explosive energy discharge in flare. However last years there are some indications that CMEs is consequence of sharp global equilibrium disturbance at slow magnetic field evolution above activity region, and flare happens after CMEs raising and even is initiated by it. As a cause of global equilibrium disturbance is drawn magnetic flux raising, motion of loop foots and other essential changing of magnetic fields in photosphere.

Comparisons of X-ray and coronagraph data show that CMEs arises at the stage of weak soft X-ray forerunner which overtakes impulsive flare phase approximately at 10 – 30 minutes [9]. Forerunner is also observed in microwave range. At the same time weak meter type III bursts are registered too. The latter indicates at appearance of accelerated electrons and open magnetic configurations.

After eruption of large CMEs rebuilding of magnetic fields is continuing during long time. Usually helmet like coronal rays above prominence are transformed into configuration with open field lines. Coronal holes are formed near eruption place. They exist about 10 – 12 hours and are sources of high velocity solar wind. After that magnetic field relaxes to its initial state. Relaxation occurs by means of magnetic reconnection and of formation after flare loop system – at first into low layers. Latter reconnection region rises in high layers with velocity 0.5 – 50 km/s. As a result new loops are formed. These loops are filled hot plasma so at first they radiate soft X-rays and after cooling they are observed in Hα lines.

CMEs rising and relaxation of magnetic field above active region are accompanied by growth of X-ray and microwave bursts, meter and decimeter continuum emission, type IV bursts that developed into storms. At the same time in interplanetary space proton fluxes are observed with time shift = 10 hours. This process also leads to formation of discrete plasma jets with its own magnetic field.

So at the moment of CMEs formation and its eruption we can expect such types of sporadic radio emission: type II and type III bursts, increased continuum emission and development of storms.

3.4. Type II bursts

It seems type II bursts accompany only CMEs connected with flares (type F events). At present time they think that flare shock generated type II burst is not directly connected with CMEs and is formed independently at the flare maximum. CMEs are formed some minutes before flare. In this model shock propagates into CMEs [10]. This agrees with observations. Type II bursts settle down inside it. Because of increased CMEs density and low Alfven velocity there is favorable conditions for generation of type II burst. On account of higher shock velocity type II burst source overtakes raising CMEs top [11].

This model is used for substantiation of existence of two independent shocks [12]. The first one, flare shock generates high frequency (> 20 MHz) type II bursts and fades at r ˜ 3 – 4 R_o. The second one, driven wave shock, is formed in interplanetary space at front of fast CMEs and generates low frequency (< 2 MHz) type II bursts. Approximately 15% of type II bursts are abruptly slowed down at r = 1.5 – 2.5 R_o. This phenomenon is observed for events with high initial shock velocities [13]. Slowing down may be because of plasma suppression at CMEs front [12], where density gradient is not high.

Correlation between type II bursts in meter range and CMEs is high. It is about 72% [14] for reliable events. But at the same time there is big group of CMEs that is not accompanied by type II bursts. They think these CMEs have velocities less than Alfven velocity. So shocks are not formed. Besides intensive CMEs there are not accompanied by type II bursts arise at backside of Sun and we can not observe type II bursts.

In decameter range data are scanty. Our experience of many years shows that, despite of generally accepted

point of view, type II bursts are observed at 10 – 25 MHz. However not all meter bursts have been continued in decameter range. So we can suppose that decameter type II bursts correlate with CMEs which have specifically parameters of velocities and masses. Simultaneous radar experiments and their observations are very important.

3.5. Type III bursts

As above-mentioned CMEs forerunner is accompanied by weak type III bursts. Other words CMEs appearance must be accompanied by increased type III burst occurrence. This fact was marked in [9], where time dependence of type III bursts occurrence was analyzed for 40 CMEs. As things turned out it has maximum about 3 times more than average value. This maximum is observed before 7.5 hours of the first CMEs detection. No doubt the same kind of thing must be at DKM waves and it can be used for short time CMEs forecast.

Besides type III bursts can be used for registration of CMEs location in the solar corona. Frequency drifts and durations of type III bursts depend from density gradients.

CMEs is large-scale density irregularity so observed type III bursts will have frequency drifts and durations different usual ones. At type III burst observation from rear edge of CMEs we shall register a decrease of frequency drift and an increase of burst duration and on the contrary for bursts from leading edge of CMEs.

For such analyses it needs data that can be got with the help of parallel observation spectrograph with difference between working channel frequencies about hundreds kHz. Such spectrograph with digital registration have been made and set in 1998.

3.6. Storms

They connect slow drifting continuum in meter range. According to Culgoora radio heliograph observations at 43, 80 and 160 MHz strengthen emission was observed at the moment of CMEs leading adge passing through corresponding plasma level in corona [15]. This fact was corroborated by other observations [5,16]. So the similar situation seems to be at DKM waves.

4. Solar activity patrol

These observations were carried out for to reveal a correlation between parameters of reflected signal and different types of solar activity; to detect phenomena in sporadic radio emission that correlate with CMEs.

4.1. Equipment for the patrol of the solar activity observations

Observations were carried out with the help of the solar measuring complex. 8-channel radio spectrograph of parallel observation and dynamic spectrograph with panoramic spectrum analyzer were used. The spectrograph of parallel observation consists of eight equal channels in the band 8 – 30 MHz. Each channel consists of receiver P250M2 with linear detector, logarithmic DC amplifier and strip chart recorder H338-8 (**Figure 2**). Characteristics of the 8-channel radio spectrograph are

sensitivity $1*10^{-23}$ W/(m^2*Hz),
dynamic range 40 dB,
channel band 1 – 10 kHz,
time constant 0.15 s.

8-channel spectrograph makes it possible to study time profiles of bursts at different frequencies, to find frequency dependencies of fluxes and frequency drifts, to appreciate sizes of burst sources, to detect burst fragmentation and so on. In 1996 – 1997 radar experiments campaigns band pass filter with band 35 Hz (**Fig. 2b**) was put into channel № 1 at the 8-channel spectrograph. Parameters of spectrograph channels during radar experiments are cited in **Table No 1**.

Dynamic spectrograph consists of panoramic spectrum analyzer (spectrum analyzer CK 4-59) in range 8 - 30 MHz, intermediate frequency amplifier (receiver P250 M2) and facsimile paper tape recorder (**Figure 3**). Sensitivity of the dynamic spectrograph is $1*10^{-22}$ W/(m^2*Hz), sweeping time is 0.5 s. The dynamic spectrograph makes it possible to define types of observed bursts more reliable.

Both spectrographs were used for registration and rapid analyses of solar activity and radio interferences during radar experiments.

Solar 30-channel radio spectrograph of parallel observation was used for registration of reflected signals. Every channel consists of receiver P399A with digital control, linear detector and integrator. Signal from integrators comes at 32-channel CAMAC ADC. ADC control and recording on hard disk carry out with the help of IBM-286 (**Fig. 4**). Sensitivity of 30-channel spectrograph is $1*10^{-22}$ W/(m^2*Hz).

Table No _1_A /UTR-2/98 Sporadic solar radio emission facility

Data d/m/y	No of beam, array	No of channel	Rec. cen. F, [kHz]	Rec. BW, Δf, [kHz]	Integrator time, [s]
10,12,13,14/ 6/1998	3 S [South]	1	8916	1	0.15
		2	10091	3	0.15
		3	12573	3	0.15
		4	14630	3	0.15
		5	16703	4	0.15
		6	20073	10	0.15
		7	25075	10	0.15
		8	29960	10	0.15
15,18,19,20/ 6/1998	3 S	1	8916	1	0.15
		2	10075	3	0.15
		3	12545	3	0.15
		4	14630	3	0.15
		5	16665	4	0.15
		6	20075	10	0.15
		7	25075	10	0.15
		8	29930	10	0.15
21/6/1998	3 S	1	8916	1	0.15
		2	10020	3	0.15
		3	12545	3	0.15
		4	14630	3	0.15
		5	16612	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15
22/6/1998	3 S	1	8916	1	0.15
		2	10020	3	0.15
		3	12545	3	0.15
		4	14630	3	0.15
		5	16612	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15

Table No _1_B/UTR-2/98 Sporadic solar radio emission facility

Data d/m/y	No of beam, array	No of channel	Rec. cen. F, [kHz]	Rec. BW, Δf, [kHz]	Integrator time, [s]
23/6/1998	3 S	1	8916	1	0.15
		2	10020	3	0.15
		3	12540	3	0.15
		4	14630	3	0.15
		5	16620	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15
25/6/1998	3 S	1	8916	1	0.15
		2	10070	3	0.15
		3	12546	3	0.15
		4	14636	3	0.15
		5	16666	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29919	10	0.15
26/6/1998	3 S	1	8916	1	0.15
		2	10015	3	0.15
		3	12545	3	0.15
		4	14630	3	0.15
		5	16612	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15
29/6/1998	3 S	1	8916	1	0.15
		2	10015	3	0.15
		3	12545	3	0.15
		4	14630	3	0.15
		5	16612	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15

Table No _1_C/UTR-2/98 Sporadic solar radio emission facility

Data d/m/y	No of beam, array	No of channel	Rec. cen. F, [kHz]	Rec. BW, Δf, [kHz]	Integrator time, [s]
30/6/1998	3 S	1	8916	1	0.15
		2	10020	3	0.15
		3	12545	3	0.15

		4	14612	3	0.15
		5	16612	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15
1/7/1998	3 EW [East-West]	1	8916	1	0.15
		2	10015	3	0.15
		3	12545	3	0.15
		4	14630	3	0.15
		5	16612	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29925	10	0.15
2/7/1998	3 EW	1	8916	1	0.15
		2	10064	3	0.15
		3	12567	3	0.15
		4	14700	3	0.15
		5	16635	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29926	10	0.15
3/7/1998	3 EW	1	8916	1	0.15
		2	10064	3	0.15
		3	12547	3	0.15
		4	14700	3	0.15
		5	16632	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29926	10	0.15

Table No _1_D/UTR-2/98 Sporadic solar radio emission facility

Data d/m/y	No of beam, array	No of channel	Rec. cen. F, [kHz]	Rec. BW, Δf, [kHz]	Integrator time, [s]
4/7/1998	3 EW	1	8916	1	0.15
		2	10063	3	0.15
		3	12548	3	0.15
		4	14700	3	0.15
		5	16655	4	0.15
		6	20080	10	0.15
		7	25055	10	0.15
		8	29926	10	0.15

4.2. Solar activity in 1998

In 1998 the further magnification of solar activity happened. The smoothed sunspot numbers in June and July was 70, however the rather significant short-term fluctuations of a level of activity were marked.

In a line Hα the short-term weak flares of classes SF and 1F in an overwhelming majority were observed only.

The daily observations of the sporadic solar radio emission in a range 8-30 MHz were carried out at the radio telescope UTR-2 during 2-5 hours, including the sessions of a radio location of the Sun also. Observations were accomplished with the help of the dynamic spectrograph and the 8-channel spectrograph of the parallel observations for eight fixed frequencies.

The solar activity in the decameter radio range was exhibited as a rare short-term phases, when the type III bursts with flux density in a range from units up to several hundreds sfu (1 sfu $=1*10^{-22}$ W/(m^2*Hz)) (**Fig. 5**) were observed mainly. And only single bursts and short-term groups of bursts with flux densities of 1000 sfu were marked. (**Fig. 6**)

The small raising of activity at the decameter range in a period from 27.06 till 9.07 is connected to common raising of solar activity in this phase.

The results of observations obtained during the sessions of the radio location of the Sun are brought in the **Table No 2**.

However, it is necessary to note that at the period from 10.06 till 4.07 in a line Hα and in x-ray range some flares by duration from several tens minutes up to several hundreds minutes were registered. During this ones in the field of flares it were marked motion of a coronal substance mass (dark filaments). During such flares the transients and the shock waves spreading up to outer corona can arise.
(SGD, 1998, № 647, 648, 649 part 1)

At the meter and the decameter ranges of radio waves such flares can be exhibited as a noise storm, a type II bursts and also as an increased frequency of emerging of large groups and type III bursts.

In 1973 - 1974 on the space station Skylab approximately 1500 type III meter-wave radio

bursts or burst groups were reported. At the same time forty coronal transients were observed above 2 R¤ by the white-light coronograph on Skylab .

The comparison of these results has shown, that the III type burst occurred in the greater numbers by 5 ... 10 hours before transient appeared in the coronograph's field of view.

Thus, after some hours after flare the transient can reach a height by some R¤ and to become a source of the reflected radar signal (if transient density will be rather high).

In a **Table No 3** the three solar flares which happened some hours before the sessions of a radio location of the Sun (09:00 - 10:00 UT) and which could be accompanied by the coronal transients are submitted. In favor of such supposition are testified:

- the significant duration of flares;
- the type II bursts which were registered in a meter range and which are excited by shock waves spreaded from area of flare;
- and observed at the decameter range storms, groups of bursts and numerous bursts of type III.

If the transients associated with these flares really existed then they could reach a height by 2 ... 5 R¤ before the beginning of the solar radar experiment.

As a result radar signal reflected from transient can forestall the signal reflected from the plasma level with frequency 9 MHz (2 R ¤).

Thus, the solar activity data obtained in optical and radio ranges during the solar radar experiments do not exclude a possibility of detection the radar signals reflected from coronal transients.

Table No 2

Decameter sporadic solar radio emission in June, July 1998

Data	The spectral class of event	Flux density in [S.F.U] Solar Flux Units
10.06	Storm of type III bursts.	= 75
12.06	Group of type III bursts at frequencies = 10 MHz. The cut-off frequency ˜ 9.5 MHz. (Bursts are absent below 9.5 MHz).	= 60 at 10 MHz
13.06	Storm of type III bursts.	< 1000
14.06	Single weak type III bursts.	< 25
15.06	Single weak type III bursts.	< 30
18.06	Bursts are absent.	-
19.06	Bursts are absent.	-
20.06	Bursts are absent.	-
21.06	Several single weak type III bursts.	= 3.5
22.06	Several single weak type III bursts.	= 21
23.06	One weak type III bursts at frequencies = 12 MHz. At frequencies 10.0 and 8.916 MHz the bursts are absent.	-
25.06	Several very weak type III bursts at frequencies > 10 MHz. At frequencies 10.0 and 8.916 MHz the bursts are absent.	-
26.06	Two groups of weak type III bursts at frequencies = 10 MHz. At frequency 8.916 MHz the bursts are	= 13.1 at 10 MHz

	absent.	
29.06	Weak storm of type III bursts.	= 567
30.06	Weak storm of type III bursts.	= 23
01.07	Weak storm of type III bursts.	= 30
02.07	Weak storm of type III bursts.	= 30.5
03.07	Weak storm of type III bursts.	= 16.5
04.07	Weak storm of type III bursts.	= 45

1 S.F.U. $=1*10^{-22}$ [W/(m^2*Hz)]

Table No 3.

Solar flares and following sporadic radio emission at metric and decametric bands

Data d/m/y	Solar flares				Metric band events			UTR-2 observations		
	Start (UT)	Max (UT)	End (UT)	Dur. min.	Start (UT)	End (UT)	Spectr. class	Start (UT)	End (UT)	Spectr. class
13/6/98	0418	0419	0439	21	0430	0448	Type II burst	0707	1100	Storm, type III burst groups
22/6/98	0422	0437	0512	50	0436	0445	Type II burst	0913	1140	Type III bursts and burst groups
29/6/98	0617	0626	0651	34	0532	1414	continuu m	0722	1211	Storm, type III burst groups

5. Instrumentation for CMEs detection

The UTR-2 radio telescope is the world's largest decametric array that operates in the frequency range 8 to 32 MHz . The full effective area of UTR-2 is near 150,000 square meters for the zenith orientation and the beam width ranges from 20 minutes to 1.5 degrees of arc. The radio telescope has a T-shaped configuration, The dimensions of the N-S arm (**Fig. 7**) is approximately 1800 m by 60 m; the dimensions of the E-W arm is approximately 900 m by 60 m. The total number of receiving broadband dipoles is 2040. The system noise temperature is determined by the brightness temperature of the galactic background, corresponding to a range of several 10s of thousands of Kelvin to several 100s of thousands of Kelvin at such low frequencies. The distributed antenna amplifier system consists of broadband, high linearity amplifiers. This system provides compensation for amplitude losses in the long cables from the dipoles to the control center, thus providing maximum sensitivity in the radio telescope. The time-delay phase system used in the radio telescope provides the same beam position for all frequencies used. There is the possibility of electronic steering of the beam in a broad cone at all azimuths, as well as simultaneous observations

with 5 spatially separated beams. The radio telescope allows us to use it in a wide variety of parallel output configurations, including independent steering of the E-W and N-S antennas. This instrument satisfies all requirements for the solar radar experiment and allows us to receive weak signals in the presence of strong man-made and natural ionospheric interferences. Special hardware and software has been designed for conducting the experiments of this project.

5.1. Equipment for monitoring interference

A dedicated spectrum analyzer was used to visually monitor the presence of interference during the experiment. This facility includes a broadband Hewlett-Packard spectrum analyzer, multichannel receiving system with a resolution of 0.3-10 kHz per channel, and a broadband correlation analyzer. This approach was used to select the transmission frequency of the SURA transmitter.

5.2 High speed digital registration

A six-channel tape recorder was used to record the signals from the UTR-2 North-South and East-West arrays for solar and moon reflection experiments (**Fig. 8**). The bandwidth of each channel is 40 kHz. We used rubidium standards for synchronization of all receivers. We used a high speed A/D converter to acquire the data for input to a computer. The output volume of data is approximately 2 or 3 Gigabytes for each experimental session. This system allowed us to synthesize a pencil beam for the UTR-2 array. For the Moon experiments this facility allowed us to obtain very accurate measurements of the frequency of the reflected wave, corresponding to frequency resolution of $\Delta f = 0.02$ to 0.05 Hz. A pilot signal is used with the tape recorder to compensate for tape speed wobble. This accuracy allows us to obtain an estimate for scattering parameters at 9 MHz in the scattering medium.

5.3 Multichannel digital correlometer

The intermediate frequency signals with bandwidths up to 40 kHz from four radio receivers were input to four digital correlometer with 2 x 64 and 2 x 48 lags (**Fig. 9**). This allowed us to obtain a frequency resolution of nearly 1 kHz. The autocorrelation function was determined in real time with an integration constant of about 1 second. These data were input to a small computer for storage and Fourier analysis. The maximum frequency coverage is about 100 kHz, corresponding to a maximum Doppler shift near 9 MHz, or a plasma flow velocity of 1500 km/sec. One-bit digitization is used in the digital correlometer. This leads to a decreased sensitivity by a factor of 1.57, but allows us to reach high reliability and stability of the equipment. Furthermore, this equipment allows us to reach a higher speed of sampling, with minimum memory requirement. The nonlinear element at the input of the system increases the problem of intermodulation interference. During this project, the nonlinear problem was studied theoretically and experimentally. It was shown that when the full power of the interference signal did not exceed the full power of the noise in the working frequency band, the interference is not significant. A similar situation exists during our experiments.

5.4 Video recorder

The video recorder was used to record the analog output of two radio receivers with bandwidths of 40 kHz (**Fig. 10**). The next step of data analysis is similar to the processing done in the VLBI URAN data analysis. The VLBI URAN system is the Ukrainian Decametric Very Long Baseline Interferometer. This facility includes mixers to transform intermediate band frequencies to base band. The output of each receiver is split into In-phase and Quadrature channels. The number

of quantization levels is four. Computer sends the signals in digital form to a video recorder. Furthermore, precise time signals are recorded on the video recorders. Data processing begins in the off-line regime with tape playback to a high-power computer, followed by spectrum analysis and determination of all parameters of radio emission.

5.5 Multichannel Postdetection Recording

Thirty radio receivers were used in the frequency range from 8 to 32 MHz in the 5-beam mode of the UTR-2 array (**Fig. 11**). The signal from the output of the detectors and integrators were digitized. The minimum sampling period is near 2 milliseconds. This facility was used to obtain reference signals by reflection from the moon and monitoring standard radio sources; this provided a method of monitoring the effects of ionospheric influence on the received signals. For the Moon reflection experiments the frequency band is from 0.3 kHz to 4 kHz, with time constant near 5 ms. The level of reflected signals are not known apriori because the amplifications of each channel are different. Furthermore, in order to reduce ionospheric refraction effects, the received signals are distributed along spatially separated beams. For the observation of reference radio sources, the frequency band is 4 kHz to 40 kHz, with time constants of 1 sec to 60 sec.

5.6 Sporadic solar radio emission facility

This is a multichannel receiving system with high dynamic range and operational range from 9 to 30 MHz (**Fig. 12**). The time resolution is near 100 milliseconds. As a rule, the observations were carried out in eight channels with frequency bands approximately 10 kHz near the frequencies of 8.9, 10, 12.6, 14.7, 16.7, 20, 25, and 30 MHz. Furthermore, it is possible to use a broadband dynamic spectrograph and heliograph for spatial localization of emission sources. This system allows to record all kinds of sporadic radio emission and corresponding dynamic spectra.

5.7. Facility regimes

The all facility regimes are show at Tables No 4,…,7.

The SUN observations at summer 1998 by SURA transmitter and UTR-2 radio telescope.

Table No _4_A/UTR-2/98 High Speed Digital Registration

date [d/m/y]	No of Rec.	No of Beam	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Fsyn. I [kHz]	Tape speed [cm/sec]	Atten. dir/ref [dB]	Pilot signal [kHz]
10/06/98	1	3 NS+EW [1]	8.920	40	195	152	30/0	OFF
	2	"	8.950	40	"	"	"	"
	3	"	8.980	40	"	"	"	"
	4	4 NS+EW	8.920	40	"	"	"	"
	5	"	8.950	40	"	"	"	"
	6	"	8.980	40	"	"	"	"
11/06/98	No data recording because of power failure							
12/06/98	1	3 NS+EW	8.920	40	195	152	30/0	OFF
	2	"	8.950	40	"	"	"	"
	3	"	8.980	40	"	"	"	"

[2] [3]	4	5 NS+EW	8.920	40	“	“	“	“
	5	“	8.950	40	“	“	“	“
	6	“	8.980	40	“	“	“	“
13/06/98 [3]	1	3 NS	8.920	40	195	152	30/0	OFF
	2	3 NS	8.950	40	“	“	“	“
	3	3 NS	8.980	40	“	“	“	“
	4	5 NS	8.920	40	“	“	“	“
	5	5 NS	8.950	40	“	“	“	“
	6	5 NS	8.980	40	“	“	“	“
14/06/98	1	3 NS	8.926	40	195	152	30/0	
	2	3 NS	8.956	40	“	“	“	
	3	5 NS	8.926	40	“	“	40/10	
	4	5 NS	8.956	40	“	“	30/0	
	5	E-W	8.926	40	“	“	“	
	6	E-W	8.956	40	“	“	40/10	
15/06/98	1	1 NS	8.926	40	195	152	30/10	
	2	3 N-S	8.926	40	“	“	20/0	
	3	3 N-S	8.956	40	“	“	40/20	
	4	1 NS	8.956	40	“	“	30/10	
	5	E-W	8.926	40	“	“	30/10	
	6	E-W	8.956	40	“	“	40/20	

Table No _4_B/UTR-2/98 High Speed Digital Registration

date [d/m/y]	No of Rec.	No of Beam	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Fsyn. I [kHz]	Tape speed [cm/sec]	Atten. dir/ref [dB]	Pilot signal [kHz]
19/06/98	1	1 NS	8.935	40	195	152	30/0	33
	2	3 NS	8.935	40	“	“	“	“
	3	5 NS	8.935	40	“	“	“	“
	4	sec. 1 EW	8.935	40	“	“	“	“
	5	sec. 2 EW	8.935	40	“	“	“	“
	6	sec. 3 EW	8.935	40	“	“	“	“
20/06/98	1	1 NS	8.926	40	195	152	20/0	33
	2	3 NS	8.926	40	“	“	“	“
	3	3 NS	8.956	40	“	“	“	“
	4	1 NS	8.956	40	“	“	30/10	“
	5	EW	8.926	40	“	“	“	“
	6	EW	8.956	40	“	“	“	“
	1	1 NS	8.926	40	195	152	20/0	33

21/06/98	2	3 NS	8.926	40	“	“	“	“
	3	3 NS	8.956	40	“	“	“	“
	4	1 NS	8.956	40	“	“	30/0	“
	5	EW	8.926	40	“	“	“	“
	6	EW	8.956	40	“	“	“	“
22/06/98	1	1 NS	8.926	40	195	152	30/0	33
	2	3 NS	8.926	40	“	“	“	“
	3	3 NS	8.956	40	“	“	“	“
	4	1 NS	8.956	40	“	“	“	“
	5	EW	8.926	40	“	“	“	“
	6	EW	8.956	40	“	“	“	“
23/06/98	1	1 NS	8.926	40	195	152	30/0	33
	2	3 NS+EW	8.926	40	“	“	“	“
	3	3 NS+EW	8.956	40	“	“	“	“
	4	1 NS	8.956	40	“	“	“	“
	5	5 NS	8.926	40	“	“	“	“
	6	5 NS	8.956	40	“	“	“	“
25/06/98	1	1 NS	8.926	40	195	152	30/0	
	2	3 NS+EW	8.926	40	“	“	40/10	
	3	3 NS+EW	8.956	40	“	“	40/10	
	4	1 NS	8.956	40	“	“	40/10	
	5	5 NS	8.926	40	“	“	30/0	
	6	5 NS	8.956	40	“	“	“	

Table No _4_C/UTR-2/98 High Speed Digital Registration

date [d/m/y]	No of Rec.	No of Beam	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Fsyn. I [kHz]	Tape speed [cm/sec]	Atten. dir/ref [dB]	Pilot signal [kHz]
26/06/98 [1] mist. at arr. oper.	1	3 NS	8.926	40	195	152	30/0	OFF
	2	3 NS+EW	8.926	40	“	“	40/10	“
	3	3 NS+EW	8.956	40	“	“	40/10	“
	4	3 NS	8.956	40	“	“	40/10	“
	5	3 NS	8.926	40	“	“	30/0	“
	6	3 NS	8.955	40	“	“	“	“
27/06/98	No data recording because of Sura transmission failure							
29/06/98 [2] P-250 M2	1	1 NS	8.920	14	208	76	0.5Vp/p	OFF
	2	3 NS+EW	8.920	14	“	“	“	“
	3	3 NS+EW	8.956	14	“	“	“	“
	4	1 NS	8.956	14	“	“	“	“
	5	5 NS	8.920	14	“	“	“	“

ADC	6	5 NS	8.956	14	“	“	“	“
30/06/98	1	1 NS	8.915	40	195	76	30/0	33
	2	3 NS+EW	8.915	40	“	“	“	“
	3	3 NS+EW	8.915	40	“	“	“	“
	4	1 NS	8.915	40	“	“	“	“
	5	5 NS	8.915	40	“	“	“	“
	6	5 NS	8.915	40	“	“	“	“
01/07/98 Phase matrix [8 bms]	1	1 NS	8.915	40	195	152	40/10	OFF
	2	3 NS	8.915	40	“	“	40/10	“
	3	4 NS centr.	8.915	40	“	“	40/10	“
	4	5 NS	8.915	40	“	“	40/10	“
	5	6 NS	8.915	40	“	“	30/0	“
	6	8 NS	8.915	40	“	“	“	“
02/07/98 Phase matrix [8 bms]	1	1 NS	8.915	40	195	152	40/10	OFF
	2	3 NS	8.915	40	“	“	40/10	“
	3	4 NS centr.	8.915	40	“	“	40/10	“
	4	5 NS	8.915	40	“	“	40/10	“
	5	6 NS	8.915	40	“	“	30/0	“
	6	8 NS	8.915	40	“	“	“	“

Table No _4_D/UTR-2/98 High Speed Digital Registration

date [d/m/y]	No of Rec.	No of Beam	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Fsyn. I [kHz]	Tape speed [cm/sec]	Atten. dir/ref [dB]	Pilot signal [kHz]
03/07/98 Phase matrix [8 bms]	1	3 NS	8.915	40	195	152	40/10	OFF
	2	4 NS centr.	17.830	40	“	“	30/10	“
	3	4 NS centr.	8.915	40	“	“	40/10	“
	4	4 NS centr.	26.745	40	“	“	40/10	“
	5	5 NS	8.915	40	“	“	30/0	“
	6	8 NS	8.915	40	“	“	“	“
04/07/98 Phase matrix [8 bms]	1	3 NS	8.915	40	195	152	40/10	OFF
	2	4 NS centr.	17.830	40	“	“	30/10	“
	3	4 NS centr.	8.915	40	“	“	40/10	“
	4	4 NS centr.	26.745	40	“	“	40/10	“
	5	5 NS	8.915	40	“	“	30/0	“
	6	8 NS	8.915	40	“	“	“	“

Table No. 5

Schedule of Multi-channel digital correlometer

Date 1998	Input channels I Band, Mhz	I Shift, degree*	II Band, Mhz	II Shift, degree*	III Band, Mhz	III Shift, degree*	IV Band, Mhz	IV Shift, degree*
6-12	8.91-8.95	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-13	8.91-8.95	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-14	8.91-8.95	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-15	8.91-8.95	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-18	8.91-8.95	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-19	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-20	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-21	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-22	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-23	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-25	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-26	8.90-8.94	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
6-30	8.895-8.935	0	8.94-8.98	0	8.97-9.01	0	9.00-9.04	0
7-1	8.89-8.93	0	8.92-8.96	0	8.89-8.93	-1.5	8.89-8.93	+1.5
7-2	8.895-8.935	0	8.93-8.97	0	8.895-8.935	-1.5	8.895-8.935	+1.5
7-3	8.895-8.935	0	8.93-8.97	0	8.895-8.935	-1.5	8.895-8.935	+1.5
7-4	8.895-8.935	0	8.93-8.97	0	8.895-8.935	-1.5	8.895-8.935	+1.5

* - spatial shift of the antenna beam from the direction to the Sun to the north (+) or to the south (-).

The SUN observation at summer session 1998 by SURA transmitter and UTR-2 radiotelescope.

Table No 6_A/UTR-2/98 Video Recorder Registration

data d/m/y	No of Rec.	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Phase comp.	F syn. [kHz]	Atten. dir/ref [dB]
10/06/98	1	8.955	20	cos	140	-26/0
UT	P-155			sin	"	"
09:06:10	2	8.925	"	cos	"	"
09:44:00	P-155			sin	"	"
12/06/98	1	8.960	20	cos	140	-30/0
UT				sin	"	"
09:05:30	2	8.925	"	cos	"	"
09:43:00				sin	"	"
13/06/98	1	8.960	40	cos	140	-24/0
UT				sin	"	"
09:05:34	2	8.925	"	cos	"	"
09:43:00				sin	"	"
14/06/98	1	8.960	40	cos	140	-24/0
UT				sin	"	"
09:05:30	2	8.925	"	cos	"	"
09:44:00				sin	"	"
15/06/98	1	8.960	40	cos	140	-24/0
UT				sin	"	"
09:07:14	2	8.925	"	cos	"	"
09:45:00				sin	"	"
18/06/98	1	8.960	40	cos	128	-24/0
UT				sin	"	"
09:10:32	2	8.925	"	cos	"	"
09:43:30				sin	"	"
19/06/98	1	8.960	40	cos	128	-24/0
UT				sin	"	"
09:06:46	2	8.925	"	cos	"	"
09:43:16				sin	"	"

Table No 6_B/UTR-2/98 Video Recorder Registration

data d/m/y	No of Rec.	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Phase comp.	F syn. [kHz]	Atten. dir/ref [dB]
20/06/98 UT 09:08:11 09:45:30	1 2	8.960 8.925	40 "	cos sin cos sin	128 " " "	-24/0 " " "
21/06/98 UT 09:08:49 09:45:00	1 2	8.960 8.925	40 "	cos sin cos sin	128 " " "	-24/0 " " "
22/06/98 UT 09:12:30 09:45:00	1 2	8.960 8.925	40 "	cos sin cos sin	128 " " "	-24/0 " " "
23/06/98 UT 09:12:26 09:50:00	1 2	8.960 8.925	40 "	cos sin cos sin	128 " " "	-24/0 " " "
25/06/98 UT 09:15:39 09:55:00	1 2	8.960 8.925	40 "	cos sin cos sin	128 " " "	-24/0 " " "
26/06/98 UT 09:13:40 09:50:20	1 2	8.960 8.925	40 "	cos sin cos sin	128 " " "	-24/0 " " "
30/06/98 UT 09:09:53 09:48:10	1 2	8.945 8.915	40 "	cos sin cos sin	128 " " "	-32/0 " " "

Table No 6_C/UTR-2/98 Video Recorder Registration

data d/m/y	No of Rec.	Rec. cen. F, [MHz]	Rec. BW ΔF [kHz]	Phase comp.	F syn. [kHz]	Atten. dir/ref [dB]
01/07/98	1	8.945	40	cos	128	-28/0
UT				sin	"	"
09:10:04	2	8.915	"	cos	"	"
09:48:00				sin	"	"
02/07/98	1	8.940	40	cos	128	-28/0
UT				sin	"	"
09:09:50	2	8.915	"	cos	"	"
09:46:00				sin	"	"
03/07/98	1	8.940	40	cos	128	-12...-30/0
UT				sin	"	"
09:09:52	2	8.915	"	cos	"	"
09:46:00				sin	"	"
04/07/98	1	8.940	40	cos	128	-24/0
UT				sin	"	"
09:10:53	2	8.915	"	cos	"	"
09:50:00				sin	"	"

Table No _7_A/ SURA /98 SURA transmitter regimes

Date [d/m/y]	No of Tran.	UT start UT finish	Tran. cen. F, [MHz]	Power [kW]	Mode τ/ Duar	F_{0f2}, [MHz]	Remarks
10/06/98	1	09:06 -	8.916 &		S1	6.1*	
	2	09:21	8.953		1.35/		
	3				930		
11/06/98	No data recording because of power failure						
12/06/98	1	09:06 -	8.916 &		S1	7.6	
	2	09:21	8.953		1.35/		
	3				930		
13/06/98	1	09:06 -	8.916 &		S1	---	
	2	09:21	8.953		1.35/		
	3				930		
	1	09:06 -	8.916 &		S1	6.9	

14/06/98	2	09:21	8.953		1.35/		
	3				930		
15/06/98	1	09:06 -	8.916 &		S1	6.4	
	2	09:21	8.953		1.35/		
	3				930		
18/06/98	1	09:07 -	8.916 &		S4	6.4	
	2	09:22	8.953		1.35/		
	3				940		

Table No 7_B/SURA/98 SURA transmitter regimes

date [d/m/y]	No of Tran.	UT start UT finish	Tran. cen. F, [MHz]	Power [kW]	Mode	F_{0f2}, [MHz]	Remarks
19/06/98	1	09:07 -	8.916 &		S4	6.8	
	2	09:22	8.953		1.35/		
	3				940		
20/06/98	1	09:08 -	8.916 &		S4	6.2*	
	2	09:23	8.953		1.35/		
	3				940		
21/06/98	1	09:08 -	8.916 &		S4	5.4*	
	2	09:23	8.953		1.35/		
	3				940		
22/06/98	1	09:08 -	8.916 &		S4	5.4*	
	2	09:23	8.953		1.35/		
	3				940		
23/06/98	1	09:12 -	8.916 &		S4	5.1	
	2	09:27	8.953		1.35/		
	3				940		
25/06/98	1	09:13 -	8.916	240	CW	5.3	aptron out
	2	09:28		250			
	3			230			

Table No _7_C/SURA/98 SURA transmitter regimes

date [d/m/y]	No of Tran.	UT start UT finish	Tran. cen. F, [MHz]	Power [kW]	Mode	F_{0f2}, [MHz]	Remarks
26/06/98	1	09:13 -	8.916 &	240	+2-2s	4.2	
	2	09:28	8.953	240			
	3			220			

27/06/98	The Sura transmission is failure						
29/06/98	1	09:13 -	8.916 &	240	S4	6.6	
	2	09:28	8.953	240			
	3			230			
30/06/98	1	09:10-	8.900-29	240	LFS 1	6.8	LFS fault
	2	09:26		240			
	3			230			
01/07/98	1	09:10-	8.900-29	240	LFS 1	7.6	
	2	09:25		230			
	3			240			
02/07/98	1	09:10-	8.910-19	240	LFS 2	6.8	begin +4s
	2	09:25		230			
	3			240			

Table No _7_D/SURA/98 SURA transmitter regimes

date [d/m/y]	No of Tran.	UT start UT finish	Tran. cen. F, [MHz]	Power [kW]	Mode	F_{0f2}, [MHz]	Remarks
03/07/98	1	09:10-	8.910-19	240	LFS 2	6.7	
	2	09:25		230			
	3			240			
04/07/98	1	09:10-	8.910-19	240	LFS 2	6.6	begin +2s
	2	09:25		230			
	3			240			

Note: S1 - freq.swiching with 4-code, bit duration 1.35 s,
transmition duration 930 s;
Note: S4 - freq.swiching with 63-code, bit duration 1.35 s,
transmition duration 940 s;
LFS 1 - linear freq. scanning, step 1 kHz, overall duration 930 s;
LFS 2 - linear freq. scanning, step 1.4 kHz, overall duration 924 s.

6. Experimental Research and Observations

From June to July, 1998, we performed several sessions of radar experiments on the sun and moon. The parameters of the transmitted signal and protocol of the experiment was sent in the initial report submitted to EOARD by NIRFI (Radio Physical Research Institute, N. Novgorod). Because of ionospheric propagation and the high power of transmission the transmitted signal was received by UTR-2 through the side lobes. These signals were used for time registration, an independent check of the modulation pattern, transmitted frequency, and power. During the solar experiments the length of transmission was 930 – 940 seconds, followed by 16 minutes of reception by UTR-2. The signal reception was done using the recording systems described in items 4.2 - 5.6.

After the end of the 16-minute reception interval, a background signal level was recorded for another 2-3-minute interval. A calibrating noise generator was used to calibrate and test all facilities also. The working regimes during the summer of 1998 are shown in Tables 5 through 10. The sun radar experiment was supported by the results of the moon radar experiment in summer 1977 and July 1998. In the Moon radar experiments we used the equipment, which have been used for sun radar experiments. The principal goal of the moon experiment is the calibration of the power, determination of ionospheric influences (absorption, refraction, and scattering), as well as the estimation of the possibility of moon surface mapping. By using a few beams in the moon experiment we observed at most times the refraction of the received signal. One example of data recorded for Moon observations by the equipment described in Section 5.2 is shown in **Figure 13**. The more intense pulses with constant amplitudes correspond to the 'direct' signal transmitted by the SURA radar; we receive this signal by ionospheric reflection with very little time delay. The less intense pulses between the 'direct' pulses correspond to the signal reflected from the Moon. As can be seen, the reflected pulses are detected with great reliability. The intensity fluctuations are determined by the effects of the propagation medium. According to the radar equation, there is agreement between calculated and measured signal amplitudes, when we take into account the parameters of transmitting and receiving antennas. With the equipment described in Section 5.2, we observed the dynamic Doppler shifts determined by Moon's orbital motion and Earth's rotation. The maximum time and frequency resolution in this experiment was 20 microseconds and 0.02 Hz. It is very important to know solar activity conditions during solar radar experiments, therefore we have continuous monitoring of solar sporadic radio emissions with the items described in 5.6.

Because the Moon cannot always be used as a calibration source during solar radar experiments we have investigated alternate methods for determining ionospheric effects on the reflected signal. This procedure is especially important for low frequencies. One alternate method is to observe passively for sporadic solar radio emissions. Another method is to use cosmic compact radio sources to estimate the ionospheric effect, such as the radio source Virgo A, which is convenient to use in summer daytime. During this project, a theory of reflection from high turbulence plasma in the solar corona was developed. This theory provides a good explanation of the results of the J.C. James solar radar experiments at 38 MHz, and was applied to our investigations at 8.9 MHz.

6.1. Attempts of CMEs detection by "ON-OF" transmitters regime

We used very simple transmitter regime in the first steps of our Sun location sessions. "ON-OF" transmitter regime used only two frequencies with complementary intensity levels at each of them (final report NIRFI 1998). We used very simple data analysis techniques when SURA transmitter works in ""ON-OFF" regime. These methods are connected with cleaning raw data and accumulation of the reflect signal with "ON-OFF" modulation period. The more interesting data has been obtained in 1996 (See **Fig. 14).** The Sun activity in this period was very low.

6.2. Attempts of CMEs detection by short Barker code transmitters sequence

At the next step of our investigation we used a short Barker code transmitters sequence. It is 4 or 7 bite code sequences with complementary intensity levels at two using frequencies (4 bit Barker code: F1 => 1101; F2 => 0010 and 7 bit Barker code: F1 => 1110010; F2=> 0001101). The main reason of using short Barker code transmitters sequence is realization compromise between possibility of accumulation reflecting signal and requirement of determination CMEs position. Unfortunately we have not convincing results.

6.3. Attempts of CMEs detection by long Barker code transmitters sequence

At the next step of our investigation we used a long Barker code transmitters sequence. This 43 bit code (binary representation: 0011110010101110101101000000100001100110110 or complement: 1100001101010001010010111111011110011001001) or 63-bit code (for example 04 July 1998 was used 63 Barker code: F1=8916 kHz =>: 000001000011000101001111010001110010010110111011001101010111111; and F2= 8953 kHz > 111110111100111010110000101110001101101001000100110010101000000) was used for

accuracy determination range position of CMEs or SUN corona. Now we have only radiometric data analysis procedures with cleaning and without cleaning. The convincing results are absent.

6.4. Attempts of CMEs detection by chirped transmissions

The chirped transmitter signal has some advantage in comparison with another signals. We used periodic chirp transmitter signals for which the frequencies increase with time. The signals of such type are not peculiar for sun bursts. This signal can be cleaned very easy and will be easy determined in conditions with strong interferences. More interesting data are present at **Figures 15** and **16**. These data have been obtained 02.07.1998 and 27.07.1997. But unfortunately it is not evidently that in these cases the reflected signal was received.

6.5. Addition possibility of CMEs detection

We used some addition possibilities for CMEs radiolocation. One of them is connected with the using of 5 beams of the UTR-2 radio telescope. The angle shift between two nearest beams was equal to 0.5° in V plane. So we have 2° field of view in V plane and our addition possibility of CMEs detection is connected with summing of reflected signals from different directions. This addition possibility will be valid if CMEs have a big reflecting surface.

The second one possibility is connected with using of the Phase matrix, which formed of 8 beams in V plane with 1.2° between them. Our Moon location sessions show that at 9 MHz lenses effects in ionosphere are very strong. The duration of one lens life is few minutes. We can assume additional amplification by lens in width angle sector when the lens is situated near SURA or UTR-2 radio telescopes.

The third one possibility is connected with presence in CMEs inhomogeneous of little space scale with high plasmas density. In this case the additional improvement of the signal/noise ratio will be obtained by using of the pencil beam.

Each of the possibilities was exanimate. Unfortunately the results which were obtained are not reliable.

7. Conclusions

Special facilities and detection procedures were developed and placed in regular operation on the UTR-2 radio telescope for sun and moon radar experiments. These facilities allowed us to reduce interference effects and to reach the maximum of sensitivity. Methods of checking ionospheric conditions simultaneously with the Sun and Moon radar experiments were developed. The signal reflected from the moon was detected with high reliability.

The Sun radar experiment required the changing transmitter frequency to 20-25 MHz. The new transmiter could be situated near the working radio telescopes. The CMEs detection can be successful only in periods of a low Sun activity at 9 MHz . The probability of CMEs existences is higher in the period of high Sun activity, but in this period the low frequency range is closed due to increasing critical frequencies in ionosphere. So the requirements for detection CMEs and appearing CMEs are contradictory propositions for the lowest frequencies. Fig 6 shows the self-closing of the Sun bursts type III. The more interesting phenomena has been detected in September 17 (1997}, when the SUN burst type III with 1000 sfu flux density at 12 MHz has been cutted off after 10 MHz. This phenomena supports our point of view.

The necessary attribute in the CMEs locations is the monitoring of Sun activity. The main task of this monitoring is determination of the time when the ionosphere is transparent end information channel Earth-Sun is exist at low frequencies (See Fig. 4). The combinations of active and passive methods of CMEs detection will be very useful in future investigations.

It is planned to continue coordinate active and passive methods of solar radar investigations, such as comparison of results from ground-based solar patrols and satellite observations with the results of our analysis. Undoubtedly, the solar radar experiments must be continued to further develop our techniques.

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